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6. AUTHOR(S)
Duncan G. Steel

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Michigan
EECS Department
1301 Beal Avenue, 1106 EECS Bldg.
Ann Arbor, MI 48109-2122

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This report summarizes the use of DURIP funds for acquisition of equipment that has greatly expanded our laboratory capability in the area of coherent nonlinear optical spectroscopy. The funds were used to purchase a regenerative amplifier for the femtosecond laser system and a computer controlled cw frequency stabilized tunable laser.

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FINAL REPORT
To the Air Force Office of Scientific Research

AFOSR-DURIP

Time Resolved Nano-Optical Spectroscopy of Coherently Excited Semiconductor Quantum Dots

AFOSR GRANT NO. F49620-99-1-0141
(PARENT AFOSR GRANT NO. F49620-96-1-0062)

GRANT PERIOD: 3/1/99 – 2/29/00

Principal Investigator: Duncan G. Steel
Departments of Electrical Engineering and Physics
Harrison M. Randall Laboratory of Physics
University of Michigan, Ann Arbor, MI 48109
734-764-4469
dst@umich.edu

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This report summarizes the use of DURIP funds for acquisition of equipment that has greatly expanded our laboratory capability in the area of coherent nonlinear optical spectroscopy. The funds were used to purchase a regenerative amplifier for the femtosecond laser system and a computer controlled cw frequency stabilized tunable laser.

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This DURIP proposal requested funding to acquire new instrumentation to facilitate the study of semiconductor quantum dots at the single quantum dot level for application to novel quantum optoelectronic devices. Semiconductor quantum dots are nanoscopic structures characterized by dimensions that are on the order of the Bohr radius for the exciton, corresponding to 100's Å for GaAs based dots. By combining recent developments in nano-optical probing with the power of coherent laser spectroscopy, we made the first demonstration of the coherent nonlinear optical response from a single exciton in a quantum dot1 as well as showing the feasibility of coherent optical control in these systems leading to wave function engineering2. Work on this program has most recently resulted in the first demonstration of optical induced and detected quantum entanglement in these systems3, a development of potentially major importance to future quantum logic devices. However, experiments in these systems to demonstrate, Rabi flopping,

more complex wave function engineering or the demonstration of a various device features in these structures requires even greater sophistication. Funds from this proposal were used to purchase critical laser hardware to extend our measurement capability to the single dot level in the time domain in support of the AFOSR Research Grant No. F49620-99-1-0045, entitled "Nano-Optics: Coherent Nonlinear Optical Response and Control of Single Quantum Dots.". Two items were purchased to enable a major expansion of our laser spectroscopy capability.

The first item is a Ti-Sapphire regenerative amplifier which will enable us to have sufficient power to achieve two objectives: 1. Raise the peak power in a single pulse to enable studies of Rabi oscillations in quantum dots; and 2. Provide enough power so that it is now possible to split the output of the system and send each pulse into a separate pulse shaper (gratin pair) thus enabling two independently tunable but highly correlated optical pulses for non-degenerate coherent nonlinear optical spectroscopy studies. The amplifier has been delivered, and final design and construction of this new capability is presently underway.

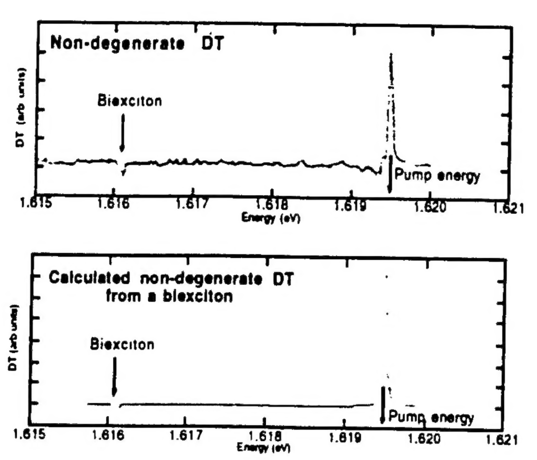

Figure 1. The non-degenerate differential transmission of a single quantum dot exciton showing the first observation by direct excitation of the biexciton. The lower curve show the theoretical prediction. The result confirms, contrary to recent expectations, that interface quantum dots have strong enough confinement to enable a bound biexciton state.

The second item (using funds from this program supplemented with support from other programs) is a cw frequency stabilized and tunable combination dye laser and Ti-Sapphire laser. This highly sophisticated and computer controlled laser is frequency stabilized to 1 part in 10^{10} and can tune continuously 10,000 cm^{-1} while maintaining an absolute wavelength accuracy of 1 part in 10^7. In the past, we have accomplished this using a dye laser that could only scan 1 cm^{-1} and then would have to be manually adjusted to scan another 1 cm^{-1}. This was very time consuming, and prevented us from carrying out numerous studies, such as the now highly successful search for the quantum dot biexciton (a search similar to finding the "needle-in-the-hay-stack"). An example of the important result is shown in Fig. 1.

In summary, these funds were used to great enhance and expand the laser spectroscopy capability of our laboratory. The new systems are critical to enabling us to carry out the experiments on the present AFOSR Grant as well as the new experiments that have been proposed in the new proposal on nano-optics to be submitted following the end of the current program.

References

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2 N. H. Bonadeo, J. Erland, D. Gammon, and D. G. Steel, Science **282**, 1473 (1998).

3 G. Chen, N. H. Bonadeo, D. G. Steel, D. Gammon, D. S. Katzer, D. Park, and L. J. Sham, Science , in press (2000).

12/21/99
Coherent Model Reg A 9000 Ti-Sapphire Regenerative Amplifier
PO #: 3000117274
Company: Coherent Laser Group
$88,198.25

12/21/99
Coherent Model 899-29 Ti-Dye laser system.
PO #3000117271
Company: Coherent Laser Group
$ 116,258.03 (was the total order)